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Influence of tuber cutting size and plant growth regulators on growth and development of *Caladium* 'Candidum'

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Abstract The result showed that the 1 cm of tuber cutting size was higher significant differed in the days to sprouting, tuber size, plant height, canopy width, and the number of leaves than the 0.5 cm of tuber cutting size. Besides, IBA at 150 ppm was higher significantly differed in the average survival rate, days to sprouting, tuber size, plant height, canopy width, and number of leaves than the others. The interaction between the tuber size at 1 cm and IBA at 150 ppm gave the highest days to sprouting, plant height, canopy width, and the number of leaves. Therefore, the *Caladium* 'Candidum' was cut at 1 cm size and soaked in 150 ppm of IBA that appropriated to induce growth after cutting within four months.

Keywords: IBA, GA_3, *Caladium*, Tuber, Cutting method

Introduction

Caladium is a member of the Araceae family. It is popular for its colourful foliage and is widely used as a pot plant or for outdoor bedding purposes. It presents few complications and grows easily. It is relatively unaffected by disease and has few pests, so as a commercial crop, it offers the advantage of lower costs. *Caladium* is a crop most found in the regions around Bangkok, including the provinces of Pathum Thani and Nonthaburi. *Caladium* production is currently worth around 3 million Thai baht annually (Caladium Association of Thailand, 1997; Deng, 2012; Essien *et al*., 2015; Hussain *et al*., 2017). In the ornamental trade, *Caladium* 'Candidum' is generally sold as a potted plant. It is a tuber for use in the landscape or home garden or as a bedding plant for late spring or early summer (Caladium Association of Thailand, 1997; Miranda *et al*., 2002).

There are three possible techniques for *Caladium* propagation: tissue culture, seeds, or tubers. Tissue culture is rarely used due to the costs involved. Seeds are predominantly employed in breeding programmes because it is a time-consuming process which introduces significant variability to the crop.

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Consequently, for commercial purposes, tubers are the most widely used method (Shah *et al*., 2007). In practice, reproduction through tuber cutting is the most used method among tuber plant production methods. Reproduction through tuber cutting is propagation made by use of a piece taken from the tuber of a plant. Tuber cutting are put in appropriate environmental conditions and are forced to form roots and suckers (Turhan, 2015). The new plants obtained in this way preserve the gene structure of the rootstock plant totally. Nybe and Raj (2004) stated that large rhizomes yielded significantly higher yields than smaller ones. Commercial growers typically make use of plant growth regulators (PGRs)in order to improve the marketable characteristics of the of their crop for economic gains. Sarkar *et al*. (2009) explained that the use of various PGRs could bring about an increase in the number of tubers per plant, the weight of the bulbs, and the overall bulb yield when applying a dip treatment method in the conditions of northern India. According to Amin *et al*. (2017), the most effective PGRs in terms of tuberose growth is GA_3, when a concentration of 300 ppm is used. The effects of PGRs tend to be rather inconsistent because environmental factors also exert their influence. Under conditions of increased humidity or when longer drying times are used, the uptake of PGRs can be increased according to laboratory test results (Stover *et al*., 2003).

Tuber cutting is an approved technique for propagation in *Caladium*, it is mainly due to the peculiar increase in the percentage and quality of the roots. It reduces the time it takes to build a tuber. However, the results of specific scientific research on this ornamental plant are deficient, and the tuber cutting size and PGRs concentrations in its growth. The study aimed to evaluate the optimum indole-3- butyric acid (IBA) or gibberellic acid (GA_3) level and tuber cutting sizes of *Caladium* ‘Candidum’ for faster growth.

Materials and methods

Study area

All the experiments were managed under greenhouse conditions at the Department of Plant Production Technology, King Mongkut's Institute of Technology Ladkrabang (KMITL) in the province of Bangkok, Thailand, between December 2021 to May 2022.

Treatments

The experiment was laid in a 2x5 factorial in a completely randomized design (CRD) with ten replications. The treatments composed of 2 factors which factor 1 used two sizes of tuber cutting: 0.5 and 1 cm, and the other factor used four concentrations of each plant growth regulator: IBA (100 and 150 ppm) and GA_3 (100 and 150 ppm), soaking to the tuber of *Caladium* for 30 minutes. The tap water was assigned to be the controlled treatment.

Plant materials

The tuber of *Caladium* 'Candidum' with an average diameter of a tuber about 6-8 cm, the tuber was prepared by removing the roots, then the cutting was divided into 0.5 and 1 cm. Then, the tubers were soaked in the four different plant growth regulator solutions or a tap water for 30 minutes followed by above treatments. Afterthat the tubers were dried and planted in a 12 x 17.5 (width x length) centimeter plastic box using a 1:1 (by volume) ratio of sand and coconut coir. After sprouting, planted in a 4.25 x 3.5 (width x length) cm pot using a 2:1 (by volume) ratio of decomposed rain tree leave and soil. The plants were transplanted into the planting material and placed in a greenhouse with 60% shading, average temperature 30-35 ℃, relative humidity 60-70%, light intensity 150-220 µmol $s^{-1}m^{-2}$, watering rate 500 ml/pot every 2 days.

Plant growth analysis

All growth parameters of the growth of *Caladium* 'Candidum' were collected at the physiological 1 month were as follows, the survival rate was evaluated by counting a normal tuber sprouting at 30 days after cutting (ISTA, 2019). The survival percentage is calculated as [% survival= (number of survival tubers/number of total tubers) x 100]. The days to sprouting was collected after planted at 30 days or the sprouted shoot about 1-2 cm length, and determined growth at 4 months were plant height in a unit of a centimeter (cm) which extended from the base of the ground to the tip of the plant, the number of leaf per plant, the canopy width at length and width of the leaf, and tuber size of tubers were calculated using a vernier caliper.

Statistical analyses

All growth parameters of plants were analysed by using the statistical analysis system IBM SPSS Statistics version 25 and statistix version 10 program. Comparisons of treatment methods were made by using Duncan's Multiple Range Test (DMRT) at the 0.05 probability level.

Results

The percentage of survival rate, the days to sprouting and tuber size of Caladium 'Candidum'

The survival rates, days to sprouting, and tuber size were significant differences ($P<0.05$) after tuber cutting in a different size. A 0.5 cm tuber was a higher percentage of survival rate (78.57 %) than a 1 cm tuber size (Table 1), but later days to sprouting (34.04 days) and smaller tuber size (3.12 cm), after planted at four months than a 1 cm size (Figure 1). Similarly, the growth and development of the *Caladium* when soaked-in different concentrations of GA_3 and IBA indicated that survival rate, days to sprouting, and tuber size were significant differences (Table 1). The percentage of survival rate was shown the highest at the 150 ppm IBA (87.93 %), the earliest days to sprouting (25.10 days), and after planted at four months, tuber size was both the IBA concentrations was 3.96 and 3.86 cm, respectively (Figure 1). The interaction between tuber cutting size and plant growth regulator concentrations affects the survival rate. A 0.5 cm tuber with soaked-in at 150 ppm IBA gave the highest percentage of survival rate (90.88 %), while the 0.5 cm tuber with soaked-in tap water was the lowest rate (64.03 %). However, the days to sprouting were found the earliest in the 1 cm tuber with soaked-in at 150 ppm IBA (21.40 days), while the 1 cm tuber with soaked-in tap water was the latest days (52.80 days). After planting at four months, the tuber size showed the largest tuber size (4.77 cm) in a 1 cm tuber soaked at 100 ppm IBA while the 0.5 cm tuber immersed at 100 and 150 ppm GA_3 was the smallest sizes (0.68 cm).

Plant height, the canopy width and the number of leaves of Caladium

The growth and development of the tuber cutting size at different was indicated of the plant height, the canopy width and the number of leaves were significant differences ($P<0.05$). The 1 cm tuber was the highest of the plant height (17.76 cm), the canopy width (12.83 cm), and the number of leaves (5.30 leaves/plant), after planted at 4 months (Table 2). The various concentrations of plant growth regulators were significantly different ($P<0.05$). The plant height, the canopy width and the number of leaves showed the highest at both 100 and 150 ppm IBA. There were 19.23 and 20.52 cm height, respectively, 16.24 and 17.78 cm width, respectively, and the highest of number of leaves was shown at the tap water and both IBA levels (100 and 150 ppm) were 5.80, 5.80 and 6.20 leaves/plant, respectively, after planted at 4 months (Table2).

Table 1. Effect of tuber cutting size and the difference concentrations of GA_3 and IBA on the percentage of survival rate, days to sprouting and tuber size of *Caladium* 'Candidum' after planted at 4 months

Tuber size	Survival rate (%)	Days to sprouting (day)	Tuber size (cm)
Tuber size			
0.5 cm	78.57 a	39.70 a	1.87 b
1 cm	74.02 b	34.04 b	3.12 a
PGRs			
Tap water	65.93 d	47.55 a	1.45 b
GA_3 100 ppm	70.86 c	41.40 b	1.69 b
GA_3 150 ppm	73.25 c	41.25 b	1.51b
IBA 100 ppm	83.50 b	29.05 c	3.96 a
IBA 150 ppm	87.93 a	25.10 d	3.86 a
Tuber size x PGRs (ppm)			
0.5 cm + Tap water	67.84 de	52.80 a	1.26 g
1 cm + Tap water	64.03 e	42.30 b	1.64 f
0.5 cm + GA_3 100	73.90 c	42.30 b	0.68 h
1 cm + GA_3 100	67.82 de	40.50 c	2.71 d
0.5 cm + GA_3 150	75.97 c	42.50 b	0.68 h
1 cm + GA_3 150	70.54 cd	40.00 c	2.35 e
0.5 cm + IBA 100	84.27 b	32.10 d	3.36 c
1 cm + IBA 100	82.72 b	26.00 f	4.77 a
0.5 cm + IBA 150	90.88 a	28.80 e	3.38 c
1 cm + IBA 150	84.98 b	21.40 g	4.34 b
F-test			
Tuber size	*	*	*
PGRs	*	*	*
Tuber size x PGRs	*	*	*
CV (%)	8.69	5.25	11.19

Different letters represent a significant difference ($P<0.05$) between treatments. The significant difference was measured by using the DMRT test.

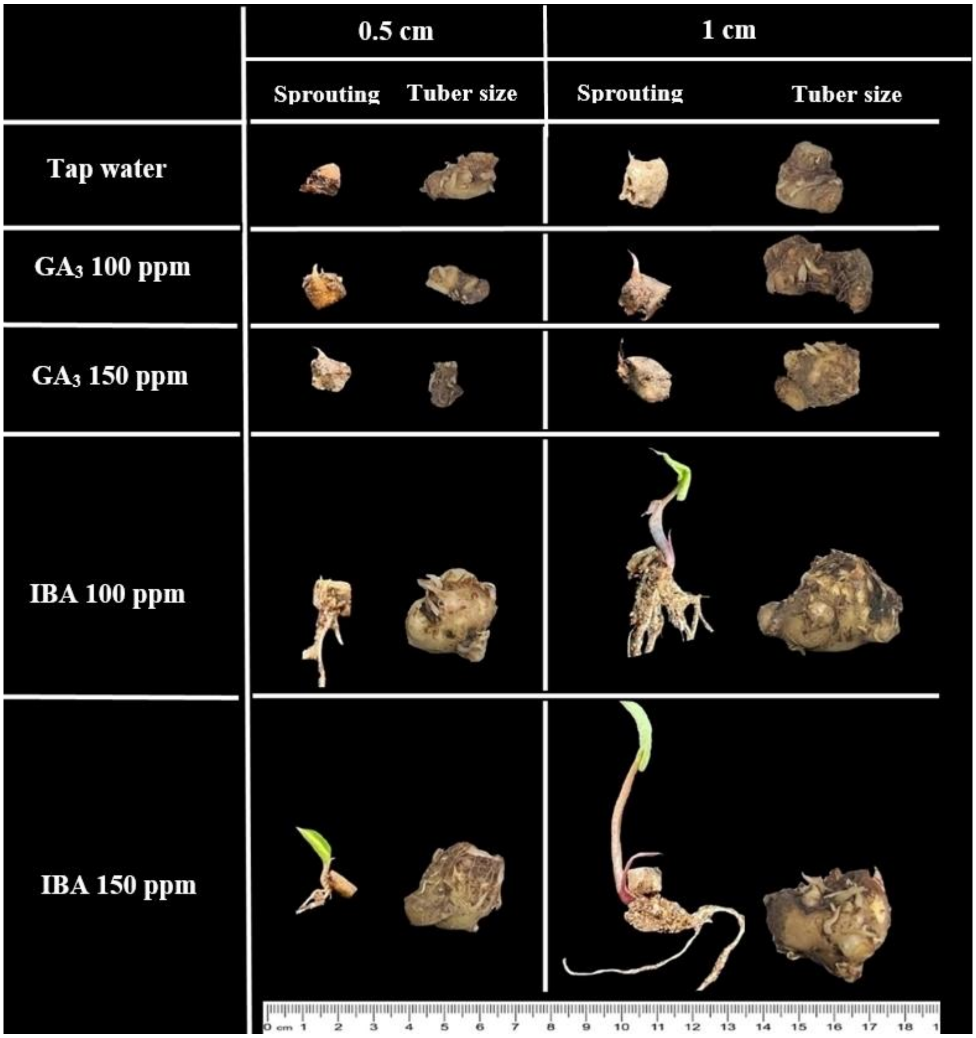

Figure 1. The sprouting and tuber size of *Caladium* 'Candidum' after cutting and soaked-in the difference concentrations of GA_3 and IBA at 4 months

The interaction between tuber cutting size and plant growth regulator concentrations on the plant height, canopy width, and the number of leaves after planting at 4 months resulted that a 1 cm tuber with soaked-in IBA at 150 ppm gave the highest of the plant height (24.35 cm) while the 0.5 cm tuber with soaked-in GA_3 at 100 ppm was the lowest height (7.24 cm). Likes, the canopy width found that the highest in a 1 cm tuber with soaked in IBA at 150 ppm (21.17 cm) while the 0.5 cm tuber with soaked-in GA_3 at 150 ppm was the lowest width (2.92 cm). Besides, the number of leaves showed the highest number of leaves 7.00, 7.10 and 7.30 leaves/plant in a 1 cm tuber combined with soaked at a tap water, 100 and 150 ppm IBA, respectively, while the 0.5 cm tuber with soaked-in GA_3 at 150 ppm were the lowest leaves number (1.20 leaves /plant) (Table 2, Figure 2).

Table 2. Effect of tuber cutting size and the difference concentrations of GA_3 and IBA on the plant height, the canopy width and the number of leaves of *Caladium* 'Candidum' after planted at 4 months

Tuber size	Plant height (cm)	Canopy width (cm)	Number of leaves
Tuber size			
0.5 cm	10.24 b	8.35 b	3.56 b
1 cm	17.76 a	12.83 a	5.30 a
PGRs			
Tap water	8.85 b	5.16 c	5.80 a
GA_3 100 ppm	10.24 b	7.07 b	2.70 b
GA_3 150 ppm	11.03 b	6.69 bc	1.65 c
IBA 100 ppm	19.36 a	16.24 a	5.80 a
IBA 150 ppm	20.52 a	17.78 a	6.20 a
Tuber size x PGRs (ppm)			
0.5 cm + Tap water	7.24 g	5.12 g	4.60 b
1 cm + Tap water	10.46 f	5.20 g	7.00 a
0.5 cm + GA_3 100	5.64 h	4.50 h	2.40 cd
1 cm + GA_3 100	14.84 e	9.68 f	3.00 c
0.5 cm + GA_3 150	4.35 i	2.92 i	1.20 e
1 cm + GA_3 150	17.71 c	10.46 e	2.10 d
0.5 cm + IBA 100	17.27 c	14.86 c	4.50 b
1 cm + IBA 100	21.45 b	17.62 b	7.10 a
0.5 cm + IBA 150	16.70 d	14.39 d	5.10 b
1 cm + IBA 150	24.35 a	21.17 a	7.30 a
F-test			
Tuber size	*	*	*
PGRs	*	*	*
Tuber size x PGRs	*	*	*
CV (%)	3.73	3.96	19.58

Different letters indicate a significant difference ($P<0.05$) between treatments. The significant difference was evaluatedby using the DMRT test.

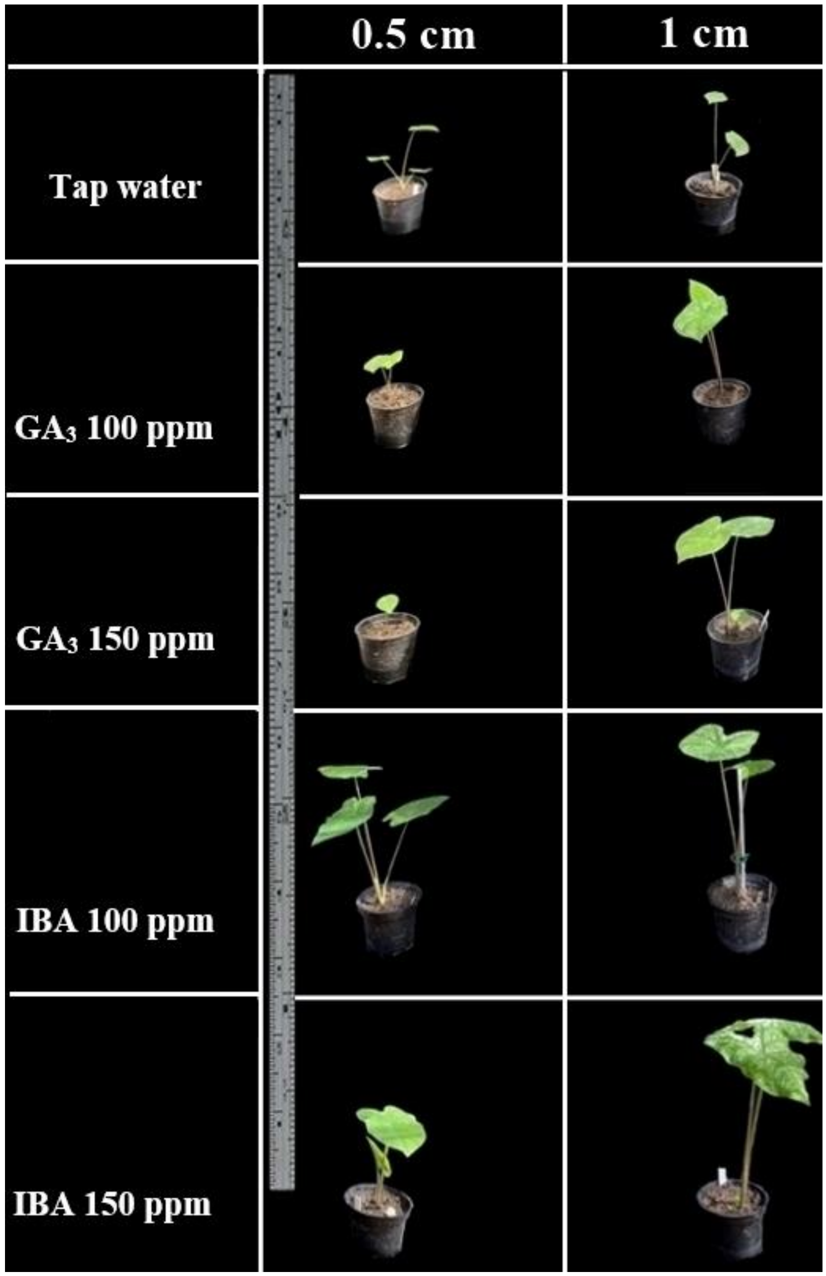

Figure 2. Effect of tuber cutting size and the difference concentrations of GA_3 and IBA on the plant height, the canopy width and the number of leaves of *Caladium* 'Candidum' after planted at 4 months

Discussion

The result showed that the 1 cm of tuber cutting size was a higher significant difference in the days to sprouting, tuber size, plant height, canopy width, and the number of leaves than the 0.5 cm of tuber cutting size which might be presenced more food reserves in larger bulbs. These results are supported by the findings of Satyavir and Singh (1998) who observed later the of days to sprouting with the large sized corms in gladiolus. This is consistent with the research results of Ahmad *et al*. (2009) who observed maximum days to sprouting, sprouting percentage, the plant height and the number of leaves and with the large sized corms in gladiolus. The results illustrate that plant height increased with the increase in bulb size (Mahanta *et al*., 1998).

The results of days to the sprouting of the *Caladium* tuber cutting found that the treatment auxin IBA concentration of 150 ppm with the tuber size at 1 cm had the highest sprouting and survival rate. This is consistent with the research results of Chaudhary *et al*. (2018) that the application of auxin IBA 100 ppm significantly the earliest sprouting of tubers of *Gladiolus x hybridus* Hort. The IBA can break down and decompose quickly to a low concentration which is appropriate to change the root meristem to be root (Tongumpai, 1994). These findings are concerning the research results of Dhiman and Gupt (2015).

The highest sprouting levels were reported after treating the seeds with 100 ppm IBA, which can be considered like GA_3 when the concentrations are the same. The improvements in seed germination following treatment with GA_3 could possibly be attributed to the greater levels of hydrolase synthesis diffusion (alpha amylase) of endogenous auxin and gibberellin-like substances. On the other hand, the cause might be the increased rate of metabolism during the process of germination. The synthesis of certain proteins can lead to more rapid cell division which in turn allows quicker and more vigorous germination (Bewley and Black, 1994; Chen *et al*., 2008). The process of seed metabolism can be assisted during germination by enzyme and coenzyme production which can then mediate the protein synthesis which is necessary to promote cell division and the growth which follows (Sajid *et al*., 2009).

The maximum plant height, canopy width and number of leaves was recorded with the tuber size at 1 cm of tuber cutting size with IBA 150 ppm. It is likely that auxin influences the growth characteristics because it is able to rapidly stimulate the cells inside the tubers, while the higher quantities of auxin in the tissue supports the conversion of tryptophan to IAA, leading to the promotion of cell division and elongation (Amin *et al*., 2017). These findings concurred with the results reported by Bhattacharjee (1983) in the context of gladiolus, and of Jana and Biswas (1979) and Mukhopadhyay and Bankar (1983) in the case of tuberose. The use of plant growth regulators to enhance both cell division and cell elongation can potentially lead to greater spike length in tuberose according to Shanker *et al*. (2010) and Tiwari and Singh (2002) in tuberose. This is consistent with the research results of ~~(~~Chaudhary *et al*.~~,~~ (2018) that the application of auxin IBA 100 ppm the highest the plant height, leaf length, leafwidth and number of leaves of tubers of *Gladiolus x hybridus* Hort.

The result showed that a 1 cm of tuber cutting size with soaked-in IBA at 150 ppm was shown the highest effected on days taken for sprouting, tuber size, plant height, canopy width and number of leaves than other treatments and control. Therefore, the *Caladium* ‘Candidum’ was cut at 1 cm size and soaked in 150 ppm of IBA appropriated to induce growth after cutting within four months.

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